U. S. ARMY PROSTHETICS RESEARCH LABORATORY
Walter Reed Army Medical Center
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Technical Report 6204

POROUS LAMINATES

A MANUAL FOR THE PREPARATION OF ABOVE AND BELOW ELBOW POROUS PROSTHESES

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U. S. ARMY PROSTHETICS RESEARCH LABORATORY
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* Qualified requesters may obtain copies of this request from ASTIA

ABSTRACT

Techniques for the fabrication of porous plastic prostheses for above and below elbow amputees are presented. The presentation is arranged in shop manual form for use by prosthetists.

INTRODUCTION

I. INTRODUCTION

The problem of perspiration and its removal from the amputee's arm and leg stumps encased in sockets has engaged the attention of the doctor and limb fitter for as long as prosthetic limbs have heen fitted. In the early days of leather prostheses, a few months of wear during the summer was sufficient to cause the leather to rot and degrade because of perspiration. Since it was not possihle to easily wash leather prostheses, severe hygienic prohlems were created. Efforts to coat leather with plastic films to overcome this difficulty were only partially successful, for in many instances the adhesion of the coating was poor and frequent re-coatings were necessary. With the advent of the all-plastic arm, it hecame possihle to thoroughly wash the socket and virtually eliminate the hygienic problem. However, hecause the plastic did not permit diffusion of water vapor, sweat gathered profusely in the socket and became a source of discomfort and irritation. Efforts to permit diffusion of sweat by drilling gross holes in the prostheses were not very successful. Although this practice permitted greater removal of sweat than in undrilled prostheses, the strength characteristics were seriously affected when a sufficient number of holes were cut to permit adequate removal. Another disadvantage of the hole-drilling technique was that there still remained hetween the holes a comparatively large surface of impervious plastic which could block large numbers of sweat pores and permit puddling between the plastic and the stump.

It appeared that for optimum socket ventilation a porous plastic socket should be developed which contained a large number of interconnected minute pores. Such a socket should permit rapid diffusion of sweat with minimal blocking of sweat pores. Furthermore, such material should be easily cleansable hy soaking in detergent, followed by flushing with water. The design criteria which were finally outlined for the desired socket material were the following:

1) The socket material shall have a uniform distribution of minute pores which would result in high porosity without hlockage of sweat pores.

2) It shall be easily cleansable.

3) Porous socket fabrication procedures shall conform with the well-known fahrication procedures current in the practices of upper-extremity prosthetics as closely as possible.

Procedures for preparing porous upper extremity prostheses, utilizing the design criteria as a guide, were developed and are presented in this manual.

LAMINATING MATERIALS

II. LAMINATING RESINS

The resins used for all laminations to be described are of the epoxy type. The epoxies are liquid resins that cure to hard, rigid products with the addition of curing agents, called hardeners. The cure may be carried out at room temperature or at elevated temperatures and unlike the polyesters, the cure of the epoxies are not air inhibited.

The particular curing temperature employed usnally depends on two factors, the first is the type of hardener, the second is the speed of curing desired. The two main types of hardeners used are the amine and the polyamide. If the amine hardeners, such as curing agent T-1[1] or ERL 2793[2] are used, a rapid cure results, whereas if the polyamide type, such as Versamid 140[3] is used, a much slower cure results. The actual curing time also depends on how thick the laminate is made, the resin may set up in 15-20 minutes with the amine curing agents, particularly on a warm day. If, on the other hand, a polyamide curing agent is used, even in thick sections, it will take several hours for the laminate to set up. When a rapid cure is desired, the laminate may be placed in an oven at temperatures ranging from 200-230 degrees Fahrenheit for 1-3 hours. A more leisurely cure can be effected at 100-120 degrees Fahrenheit in 6-8 hours. Use of an amine curing agent causes the laminate to set up at room temperature. This is usually followed by a post cure at elevated temperature to make certain that complete cure has been effected.

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1 Shell Chemical Co., 380 Madison Avenue, New York, N. Y.

2 Union Carbide Chemical Co., 30 E. 42nd Street, New York, N.Y.

3 General Mills Chemical Division, Kakakee, Illinois

The "pot life" of the liquid resin mixture using an amine curing agent may be as short as 5 - 6 minutes, whereas that of the polyamide is never less than 30 minutes and usually much longer.

The main drawbacks to using the amine curing agents are their toxicity and sensitivity to moisture.

The problem of toxicity may be controlled by proper ventilation and handling precautions, such as protective creams and/or gloves. The sensitivity to moisture presents a more difficult problem. Unless the amine type curing agents are stored in moisture-tight containers they will absorb the moisture in the air and become less reactive. This condition is particularly noticeable during the humid months of the year when laminates are allowed to cure at room temperatures. The surfaces of such laminates are often tacky due to insufficient curing. This problem can be minimized by curing the laminates at elevated temperatures.

For these reasons the polyamide type curing agents were used in this work. These materials do not present any handling problem except to the hypersensitive individual, and although they will absorb moisture upon long exposure, the cure is not affected adversely by atmospheric moisture.

An additional feature of the polyamides is their ability to flexihilize the epoxy resins when used in high concentrations. In low concentrations they produce similar rigid laminates as the amine hardeners.

In the experimental work conducted to develop the technique for preparing porous laminates the following resin system was used:

		Pts. by Wt.
Epoxy Resin	ERL 2795[1]	65
Curing Agent	Versamid 140[2]	35
Solvent	Trichloroethylene	43

Another epoxy resin that may be used in place of the ERL 2795 is Epon 815[3]. Satisfactory results have been obtained with this product when used in the same proportions and under the same conditions as ERL 2795.

The actual amount of resin mixture needed for a particular lamination may be best determined by the individual limb fitter. The following table will serve as a guide for determining the correct proportions of materials necessary.

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1 Bakelite Chemical Division, Union Carbide Chemicsl Co., New York, N. Y.

2 General Mills Chem. Division, Kankakee, Illinois

3 Shell Chemical Co., New York, N.Y.

TABLE I

Amount of * Total Resin Mixture Needed	Amount of ERL 2795 Necessary	Amount of Versamid 140 Necessary	Amount of Trichloroethylene Necessary	Typical Applications
50	23.0 gm.	12.0 gm.	15.0 gm	
75	34.0	18.5	22.5	
100	45.5	24.5	30.0	Short BE
125	56.0	30.5	37.5	
150	68.0	37.0	45.0	Medium BE
175	79.5	43.0	52.5	
200	91.0	49.0	60.0	Long BE
225	102.5	55.0	67.5	
250	114.0	61.0	75.0	Long BE
275	125.0	67.0	83.0	
300	136.5	73.5	90.0	Shoulder

* Total resin mixture includes resin, curing agent, and solvent.

III. FILLER MATERIALS

The filler material is the orthopedic tubular knit nylon stockinet commonly used by the prosthetic industry. In addition to this a nylon Ban Lon* stockinet is required for the outer and inner layers to give the desired surface appearance and texture. This material is manufactured in various widths.

*The Adler Co., Cincinnati 14, Ohio

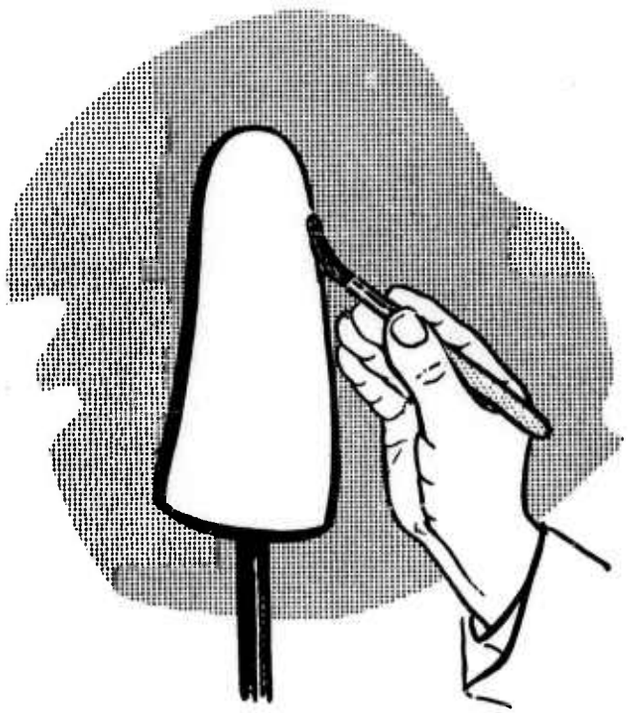
LAMINATING PROCEDURES

DOUBLE WALL, BELOW-ELBOW PROSTHESIS

PLASTER BUILDUP

IV. FABRICATION OF A DOUBLE WALL, BELOW-ELBOW, PROSTHESIS

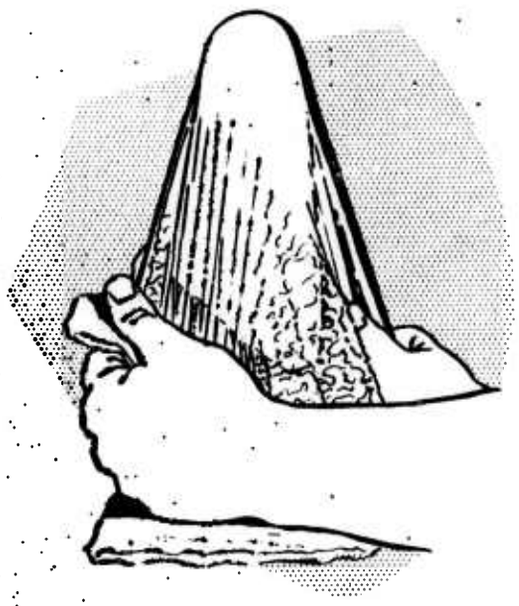
Part A. Plaster Buildup



Step 1. Mold Preparation

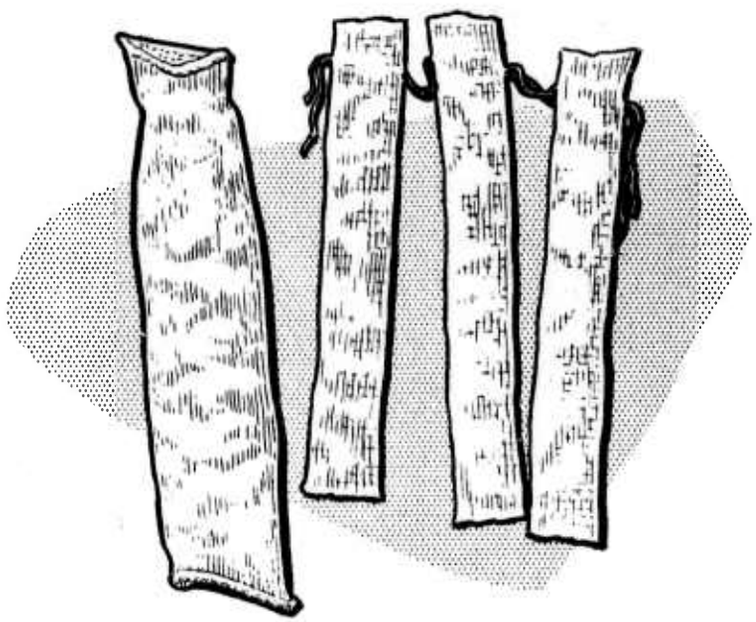
Prepare the stump model in the usual manner. Place the model in a vise, distal end up, and coat it with a release agent such as Hi-Glo*. Allow this coating to dry.

* Western States Lacquer, Dallas 12, Texas



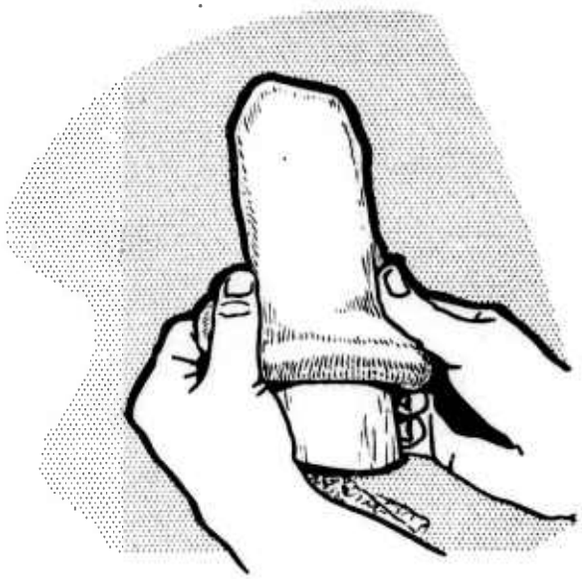
Step 2. PVA Sheet

Moisten a sheet of polyvinyl alcohol (PVA) and stretch it down over the stump model. Tie **at the base. If preferred, use a PVA** sleeve and then cap with a sheet of PVA and heat seal.



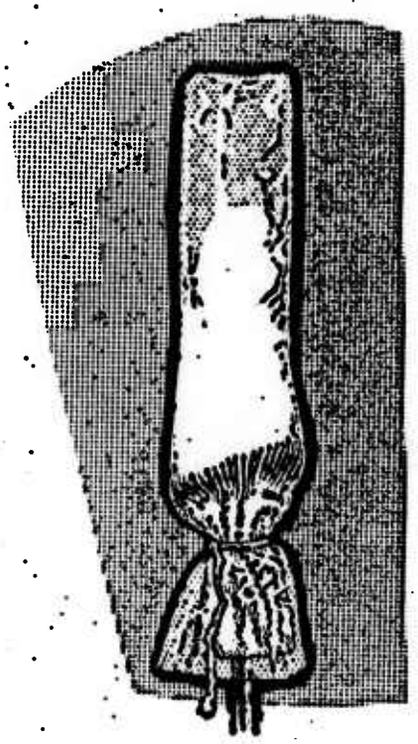
Step 3. Sew Stockinet

Cut one length of Ban Lon stockinet and three lengths of orthopedic stockinet at least 6 inches longer than the stump model. Sew the end of each piece in a curve to match the distal end of the model. Trim the excess stockinet at the sewn end.



Step 4. Stockinet Layup

Turn the Ban Lon stockinet inside out and pull over the model, then follow with two lengths of orthopedic stockinet. Tie the open ends to the base rod. Turn remaining piece of stockinet inside out and pull it over the layup. Smooth the stockinet, pull it down tightly and tie at the base.



Step 5. Pressure Sleeve

Prepare a PVA pressure sleeve in the usual manner*. Pull the sleeve down snugly over the layup and tie at the base rod.

* UCLA Manual Upper Extremity Prosthetics, Pg. 92, 1958.

Step 6 (a). Mix the Resin

Balance a disposable container *(such as a paper cup)* on a scale and add the resin, curing agent, and solvent in the proper amounts. Use Table I as a guide. The following quantities should be sufficient for the average medium BE socket:

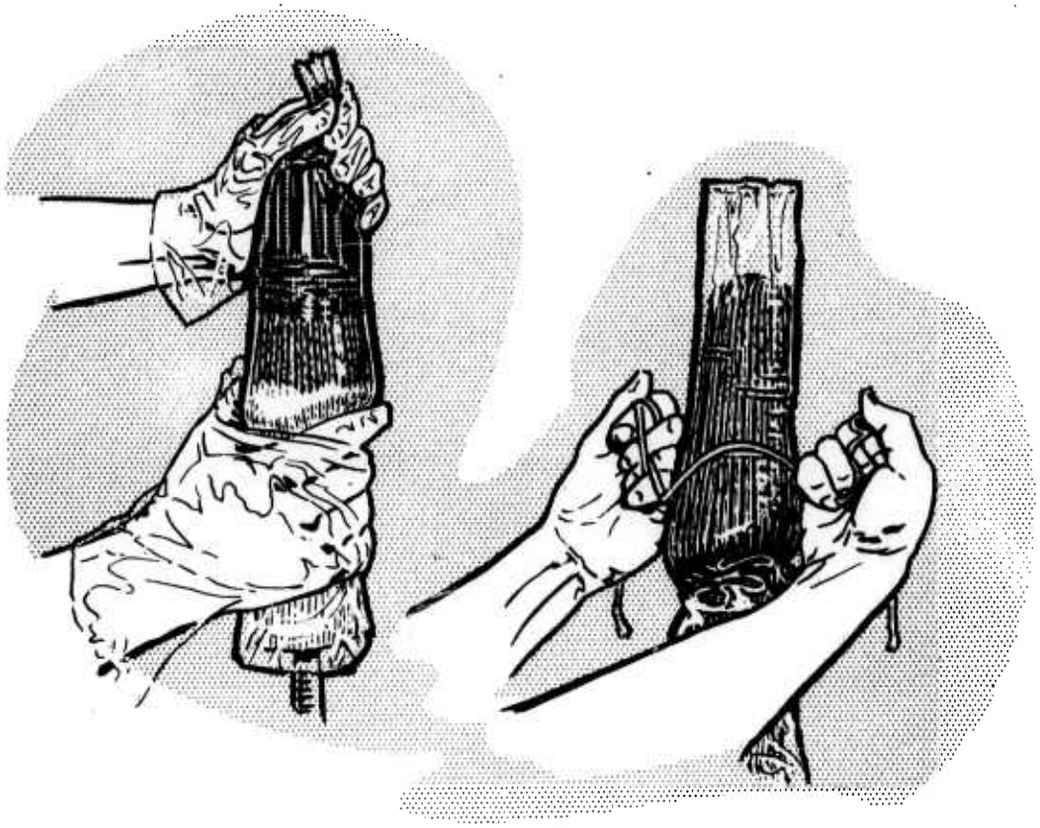
ERL 2795 *(resin)*	45.5 grams
Versamid 140 *(curing agent)*	24.5 "
Trichloroethylene *(solvent)*	30.0 "

Step 6 (b). Add the Color

Choose the appropriate color for the individual, using an epoxy based formulation. Stir the proper amount of color into the resin mixture until it is uniformly blended; 1-3 grams will be sufficient for a 100 gm. batch. The following formulas have been successfully used at APRL:

	Caucasian	Negro
Titanox RCHT *(white)*	32 g.	7 g.
Mapico Red *(Med.)*	3	3.5
Mapico Lemon Yellow	6	11
Mapico Brown	4	19
*ERL 2795	57	59

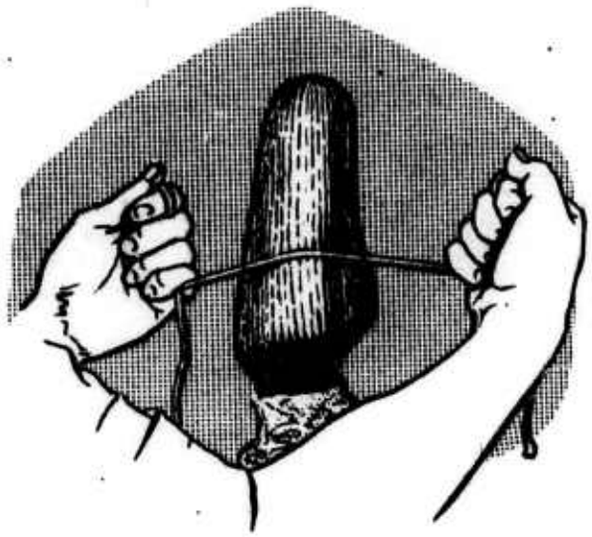
* The dry pigments were mixed with the ERL by hand and then the batch was blended on an ink mill.



Step 7. Impregnation

a) Pour the resin mixture into the open end of the PVA sleeve and work it down into the stockinet. Twisting the end of the sleeve will develop considerable force, aiding impregnation.

b) When the stockinet is fully impregnated, pull the sleeve down as far as possible and string the resin down to the proximal end of the layup until all excess resin has been strung out.



Step 8. Stringing out the Resin

Cut the PVA sleeve and remove it from the layup. Be careful not to spill the excess resin remaining in the bottom of the sleeve. Discard the sleeve and excess resin *(any spilled resin may be cleaned with isopropyl alcohol or trichloroethylene).*

String the layup down again with a heavy string until no further excess resin appears on the layup.

Step 9. Pre-cure

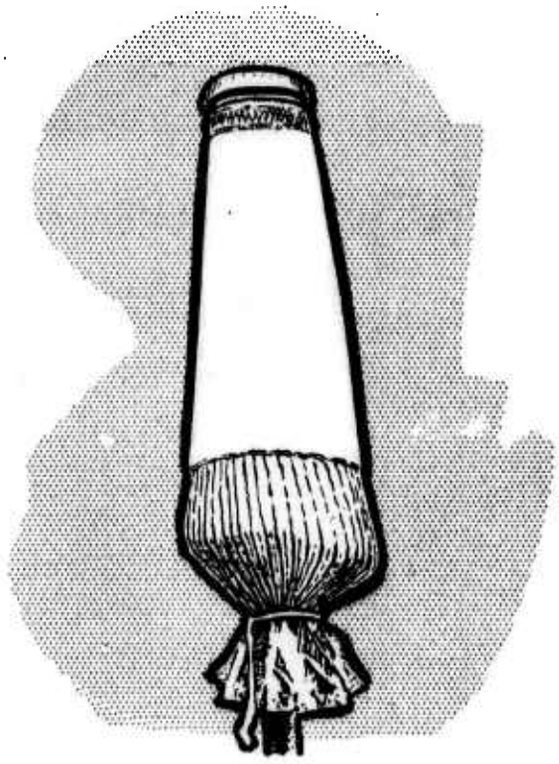
Place the layup in a pre-heated oven set at 47° C (115° F) for 30 minutes. This is known as the PRE-CURE. During this stage the solvent evaporates from the layup leaving it porous.

Step 10. Cure

Remove the layup from the PRE-CURE oven and set the oven at 100° C (212° F). At this step in the procedure, the solvent has evaporated and the resin has gelled slightly. If there are any areas in the laminate that contain excess resin, string this resin to the proximal end. When the oven has reached a temperature of 100° C (212° F), place the laminate back into the oven for one hour. During this hour the laminate will be cured sufficiently to allow the buildup of the outer socket.

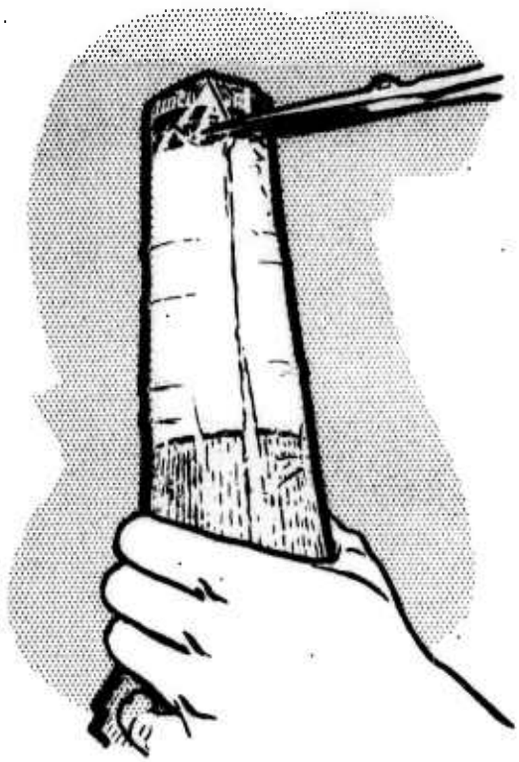
Step 11. PVA Sheet

Remove the laminate from the oven and set the oven at 47° C (115° F). As soon as the laminate is cool enough to handle, pull a sheet of PVA over the laminate socket. *(This sheet will facilitate release of the outer socket that will be laminated over this inner shell.)*



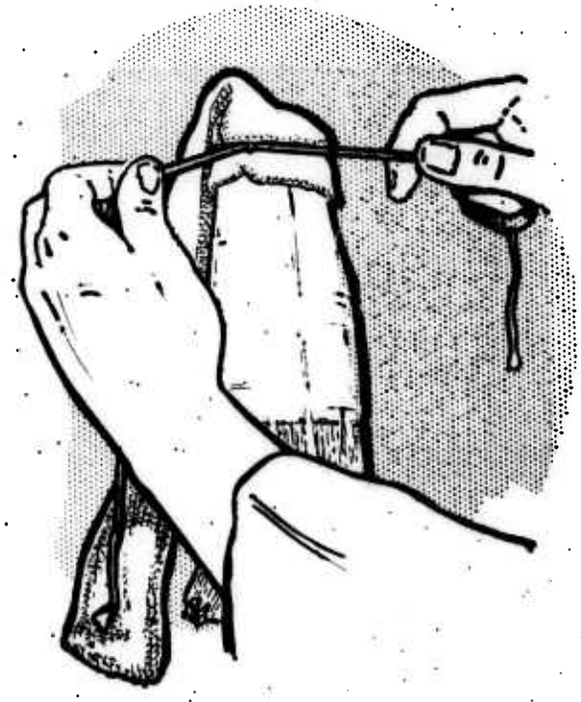
Step 12. Forearm Buildup

You are now ready for the forearm buildup. This buildup should be done in the usual manner, using either plaster of Paris or wax. The plaster is preferred because the wax may get into the pores of the prosthesis. *(For wax method see Section IV, Part B.)* After the plaster has hardened, remove the paper cone and shape the cylinder to the desired contour. Remove any plaster from the knurled surface of the wrist unit. Coat plaster with Hi-Glo.



Step 13. PVA Sleeve

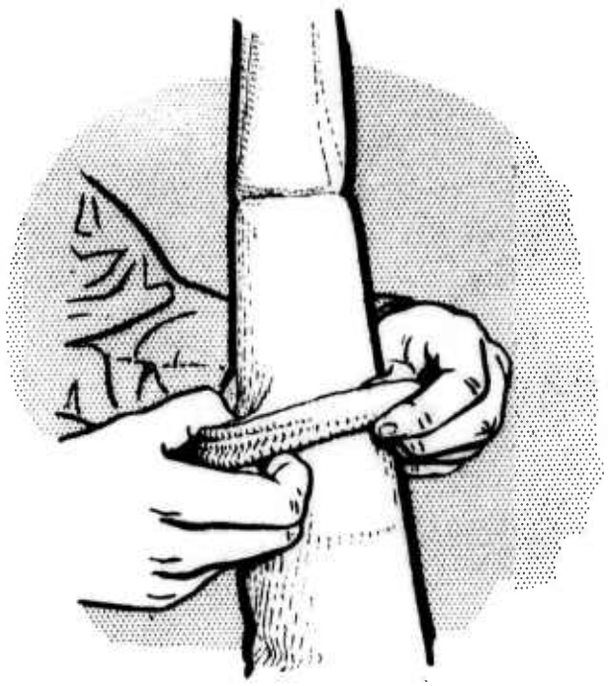
Prepare a PVA sleeve, moisten and pull down over the buildup and trim at the wrist unit.



Step 14. Layup Outer Ban Lon Stockinet

Cut a piece of Ban Lon stockinet and a piece of orthopedic stockinet 3-5 inches longer than the layup. Cut another piece of orthopedic stockinet a little longer than double the length of the layup. *(Additional lengths of stockinet may be used if extra strength is desired.)*

Turn the Ban Lon stockinet, inside out, and pull 1-2 inches over the distal end, and tie at the wrist unit. Trim excess of stockinet that is proximal to the wrist unit.



Step 15. Layup Orthopedic Stockinet

Take the short piece of stockinet and pull it over the long piece in such a manner that each piece meets at one end. *(The other end of the short piece should extend just past the middle of the long piece.)* Hold the smooth stockinet extended above the wrist unit and slip these pieces of orthopedic stockinet *(double end first)* over the free end and down until the double piece covers the entire layup. Tie at the wrist unit and pull down the two pieces of extended stockinet and tie them at the proximal end. The Ban Lon piece should be on the inside.

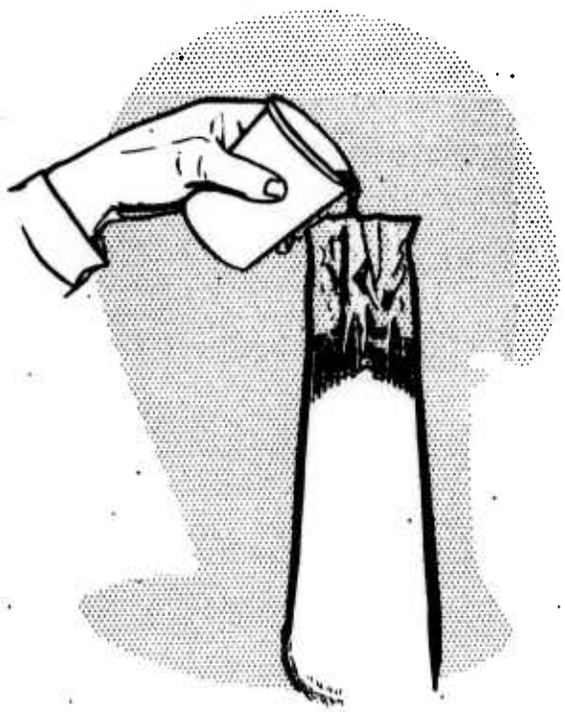
Step 16. Pressure Sleeves

Prepare two PVA sleeves in the usual manner. Turn the shiny surfaces to the inside. Put one sleeve aside for later use; take the other sleeve and pull it over the layup and tie around the pipe at the proximal end.

Step 17. Mix Resin

Mix resin and color as described in Step 6. The following quantities should be sufficient for the average medium BE forearm:

ERL 2795	68 g.
Versamid 140	37 g.
Trichloroethylene	45 g.
Pigment	3/4 - 1½ g.



Step 18. Impregnation

Pour the resin into the PVA sleeve and work it into the stockinet. When the stockinet is fully impregnated, pull the sleeve down as far as possible and string all excess resin down out of the layup.

Step 19. Strip Sleeve

After the layup has been thoroughly strung down, strip off and discard the PVA sleeve. Now string the layup once more to insure the removal of all excess resin.

As there may be considerable resin in the stockinet around the base pipe, it is necessary to absorb this excess resin in the scrap stockinet wrapped around the base. This will prevent the resin from being drawn back into the laminate during cure.

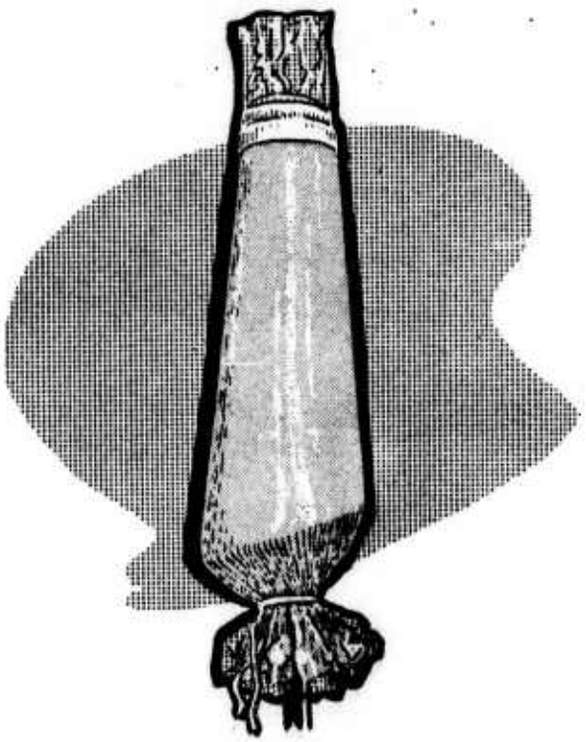
Step 20. Pre-cure

Place the layup in a pre heated oven set at 47° C (115° F) for 30 minutes to allow the solvent to evaporate.

During this pre-cure period, moisten the second PVA sleeve *(Step 15)* by wrapping it in a damp towel for 10 - 15 minutes. As the next step insures the smooth surface on the final prosthesis, it is very important that the PVA sleeve be thoroughly moistened.

Step 21. Surface Molding

Remove the layup from the pre-cure oven and pull the moistened sleeve down until the entire layup is in contact with the sleeve. Light contact pressure is the most desirable as this will result in the smooth surface required without reducing the porosity. This can be accomplished with minimum force, if the PVA has been sufficiently moistened. It is very important that the sleeve slide easily over the layup, otherwise the excess force may cause pooling of the resin. There should be no pools of resin on the stockinet at this point in the procedure; if there are, string them out.



Tape the PVA sleeve around the wrist unit to insure proper strength. Any severe undercut areas should also be taped. *NOTE: If a non-gloss finish is desired, omit this step and proceed with Step 22. If no PVA sleeve is used, the resulting laminate will not only have a dull surface but will have greater porosity.*

Step 22. Initial Cure

Place the layup in an oven pre-set at 100° C (212° F) for 60 minutes. During this period the PVA sleeve shrinks around the layup, giving the surface a smooth appearance and aiding in molding to undercuts. At the end of 60 minutes, remove the laminate and strip off the PVA sleeve. At this point the laminate should be firm and tack-free.

Step 23. Final Cure

Replace into the oven at 100° C (212° F) for 75 minutes for the final curing cycle.

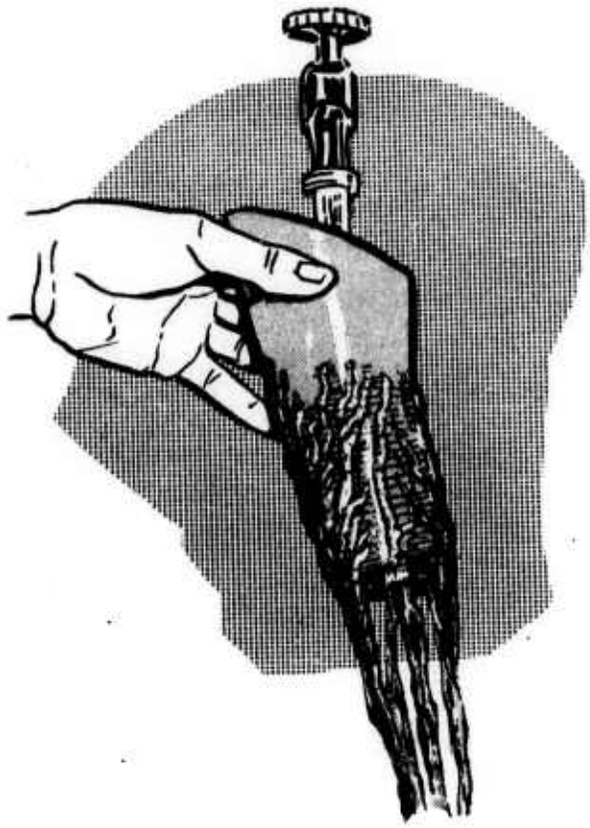
Step 24. Mold Removal

While the plastic is still warm, cut the end of the layup to the desired length. The outer socket should separate easily from the inner socket.

The plaster may be removed by striking the socket with a rubber mallet. If necessary, use a chisel to dig the plaster out of the distal end of the socket. Remove any PVA film remaining by stripping by hand or if necessary by dissolving the film with hot water.

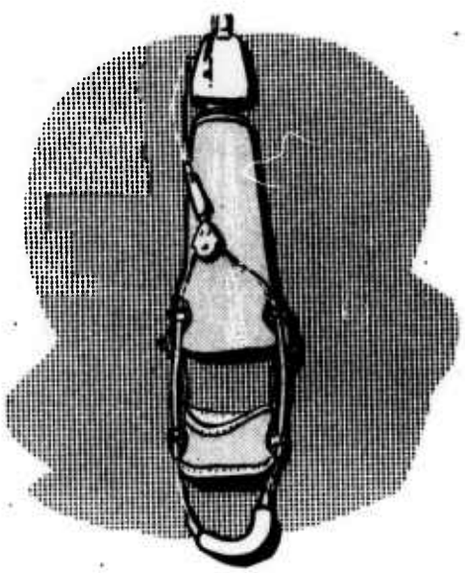
Step 25. Trim

Hold the prosthesis firmly on the amputee's stump and mark the trim line. Remove the socket and trim in the usual manner. After the socket and forearm have been properly aligned, sand the edges and bond together with liquid epoxy resin *(ERL 2795 - 65 pts., Versamid 140 - 35 pts.)*. Cure with a heat gun or place in an oven at 100° C (212° F) for 1 hour.



Step 26. Test Porosity

Test the porosity of the finished prosthesis by holding it under a water tap and allowing the water to run through the prosthesis. If the prosthesis has been prepared properly, the laminate should show homogenous porosity.



Step 27. Assemble

Complete harnessing in the usual manner.

BELOW ELBOW PROSTHESIS, DOUBLE WALL

WAX BUILDUP

SECTION IV. BELOW ELBOW PROSTHESIS, DOUBLE WALL

Part B. Wax Buildup Procedure

Steps 1 through 11.

Proceed as in Part A.

Step 12. Forearm Build-up

Make the wax forearm buildup in the usual manner* and check for the proper length and alignment. After the wax has hardened, remove the paper cone and shape the wax to the desired contour. Remove any wax from the knurled surface of the wrist unit, but leave the wax on top of the wrist unit to protect it from resin during impregnation.

Steps 13 through 19.

Proceed as in Part A.

*Use a high melting wax if possible.

Step 20. Pre-cure

Invert layup, distal end down, and place in a pre-heated oven set at 47° C (115° F) for 30 minutes to allow the solvent *(trichloroethylene)* to evaporate. During the pre-cure moisten the second PVA sleeve by wrapping it in a damp towel for 10-15 minutes.

Step 21. Surface Molding

Remove the layup from the pre-cure oven and pull the moistened PVA sleeve down with light pressure until it covers the entire layup. This light contact pressure is desirable as it will result in the smooth surface required without reducing the porosity. It is very important that the PVA sleeve slide easily over the layup to prevent possible pooling of the resin. There should be no pools on the laminate surface. It there are any, string them out. Apply tape around the wrist unit and and severe undercuts.

Step 22. Initial Cure

Replace layup, distal end down, into the oven set at 47° C (115° F) for 4 hours. *(NOTE: This initial cure, which differs from that used with the plaster buildup, prevents melting of the wax before the laminate is sufficiently rigid to support its own weight.)* Remove PVA sleeve after 4 hours.

Step 23. Final Cure

Place into an oven set at 47° C (115° F) and allow laminate to remain overnight *(at least 15 hours)*.

Step 24. Wax Meltout and Post Cure

Hang the laminate, distal end down, in a pre-set oven at 100° C (212° F) for 60 minutes. Place a pan under the laminate to catch the melting wax. During this post cure, the wax build-up should melt completely out of the laminate.

Step 25. Mold Removal

Cut the layup to the necessary length. Remove the outer socket and pull out the PVA sleeve. There will still he some small traces of wax in this outer forearm. These may he removed hy pouring hoiling water through the laminate. Remove the mold from the inner socket and discard the PVA coverings. If any wax has gotten into this socket, remove it by pouring boiling water through the socket.

Step 26. Trim and Assemhle

Hold the prosthesis firmly on the amputee's stump and mark the trim line. Remove the socket and trim in the usual manner. After the socket and forearm have been properly aligned, sand the edges and hond together with 13 parts of ERL 2795 and 7 parts of Versamid 140. Cure the bond area with a heat gun or cure for 1 hour at 100° C (212° F). Complete harnessing in the usual manner.

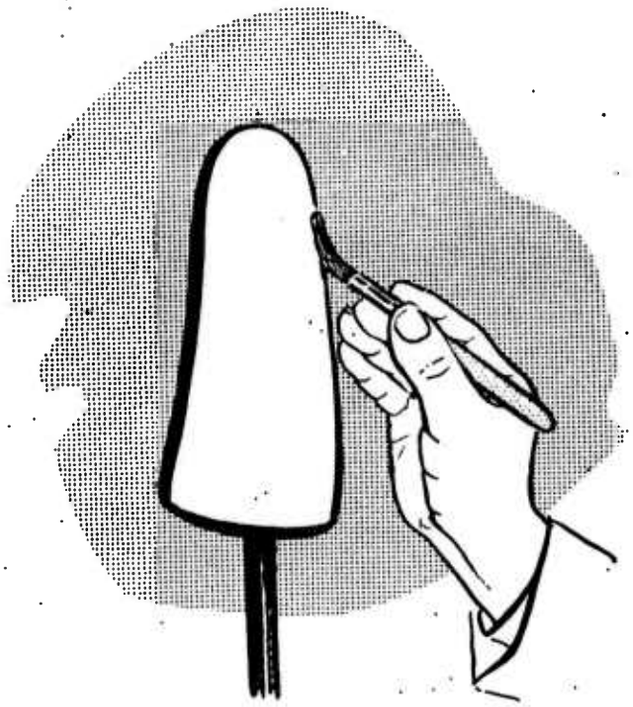
BELOW ELBOW PROSTHESIS, SINGLE WALL

MYLAR CONE METHOD

Section V. BELOW ELBOW PROSTHESIS, SINGLE WALL

The single-wall technique is divided into two methods: One method, MYLAR * cone method, is restricted to stumps of uniform conical shapes. A second method, PLASTER BUILD UP method, is for all other shapes.

PART A. MYLAR CONE METHOD



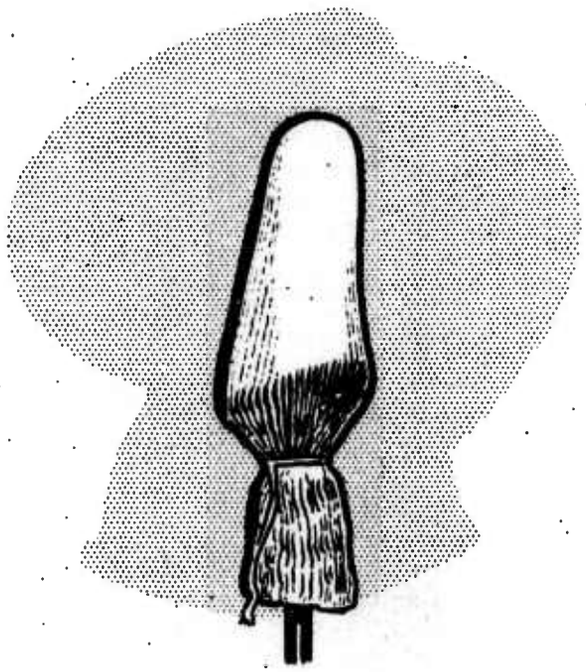
Step 1. Stump Model

Prepare the stump model in the usual manner, place model in vise, distal end up, and coat with Hi-Glo. Allow coating to dry, they pull a moistened sheet of PVA down over stump model and tie at base.

* DuPont Corporation Trademark.

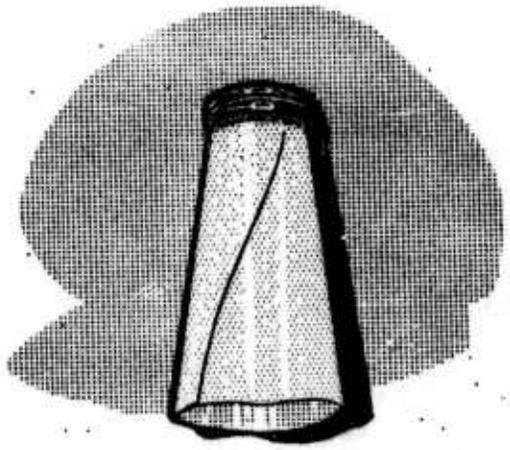
Step 2. Sew Stockinet

Cut a length of Ban Lon stockinet and three lengths of orthopedic stockinet at least 6 inches longer than the stump model. Sew the end of each piece in a curve to match the distal end of the model. Trim the excess stockinet at the sewn end.



Step 3. Layup Stockinet

Turn the Ban Lon stockinet inside out and pull over the model; follow this with two lengths of the orthopedic stockinet. Tie at the base rod. Turn the remaining piece inside out and pull it over the layup. Smooth the stockinet, pull it down tight, and tie at the base rod. Pull a sheet *(or sleeve)* of PVA over the layup and tie at the base rod. This PVA cover will protect the laminate during subsequent steps.



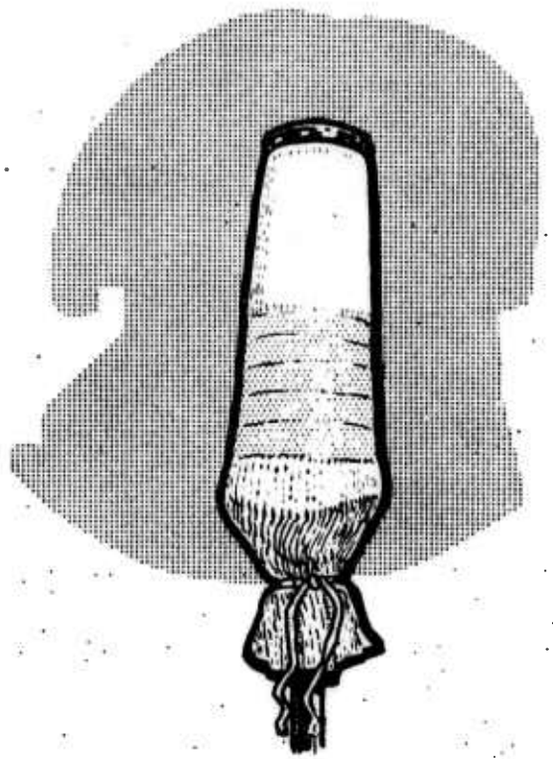
Step 4. Mylar Cone

Take an 8" x 12" sheet of Mylar *(5 - 10 mils)* and make a crayon mark halfway along one of the long sides about ¼ inch from the edge. Make a second mark ½ inch inside this mark, and two final marks 3 inches on each side from the first mark. Draw a curve through these 3 marks and cut along the line. This cut side will allow the standard adult wrist unit to fit squarely to the Mylar when it is formed into a cone.

Wrap a sheet of Mylar around the wrist unit so as to form a cone. Place the cone over the stump model and adjust the length so that the desired contour of the finished prosthesis will he obtained. The wrist unit should be fitted a minimum distance into the cone. With one hand, hold cone and wrist unit, with face of unit flat on a table. With other hand position the stump mold in the cone so that the distance between the elbow axis and the table surface corresponds to the required forearm length. Adjust the cone at the proximal end and trim off the excess. The shortest cone that will give a desirahle final forearm shape should he used, as it will give the greatest hond area hetween the forearm and the socket.

As soon as the correct conical shape is ohtained, close the cone with transparent tape. Align the socket in the usual manner. Re-check the forearm length to see that it is correct and tape the proximal end of the cone to the socket.

Adjust the wrist unit so that it is perpendicular to the longitudinal axis of the cone and almost completely protruding from the cone. Attach the unit to the cone with transparent tape. Tape all seams.



Step 5. Cone Build-up

Cut a piece of orthopedic stockinet at least 10 inches longer than twice the length of the layup. Pull the stockinet down over the entire layup so that half of the stockinet extends above the wrist unit and tie at the unit. Pull the extended piece back down over the layup, stretch smooth and tie at the base pipe. Palpate for the proximal edge of the Mylar and trace a light line around the layup just distal to the edge of the cone. Cover all areas below this line with masking tape.

Step 6. Impregnate Cone

Mix the following batch of resin:

ERL 2795	45½ g.
Versamid 140	24½ g.
Trichloroethylene	30 g.

Add enough pigment to give a slight color to the batch. Invert the layup and brush coat with this resin mixture. String down all excess resin toward the wrist unit. *(A PVA sleeve may be used instead of a brush if desired.)*

Step 7. Pre-cure Cone

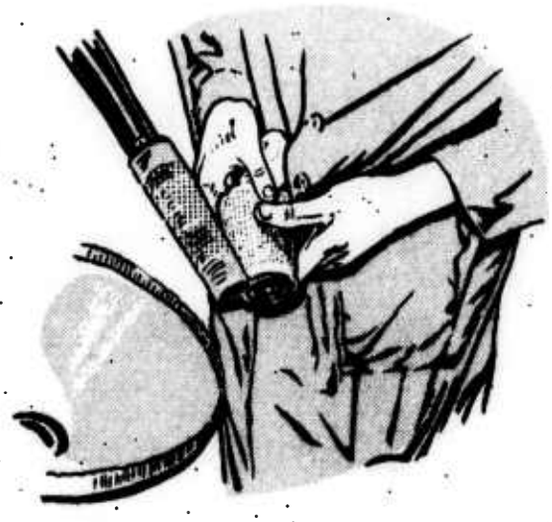
Place layup into an oven pre-set at 47° C (115° F) for 30 minutes to allow the solvent to evaporate.

Step 8. Cure

After the cone has been pre-cured for 30 minutes, increase the oven temperature to 100° C (212° F) and cure the cone for 30 minutes at this temperature. *(NOTE: If two ovens are available, have the second oven pre-set at 100° C (212° F) and place the cone in this oven for 30 minutes immediately after the pre-cure.)*

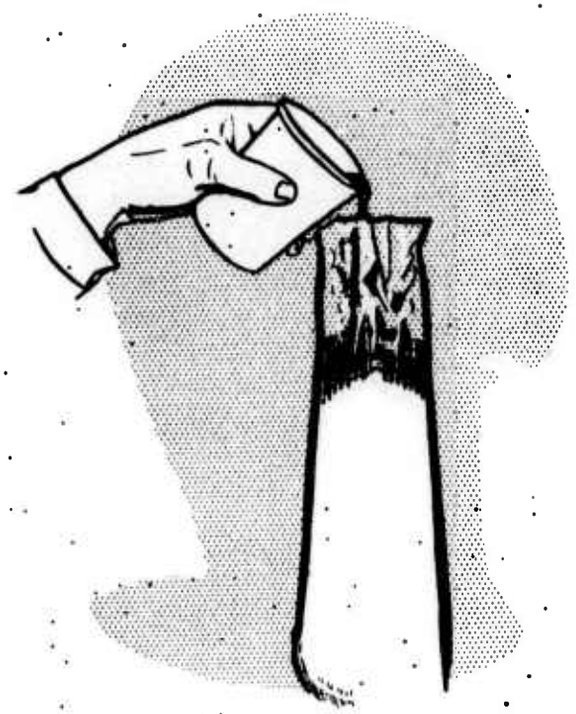
Step 9. Finishing Cone

Take the layup from the oven, remove the masking tape, and pull the cone from the inner socket. Reach inside the porous cone and remove the Mylar sheeting. Next, sand the porous cone around the wrist unit until a smooth taper is obtained.



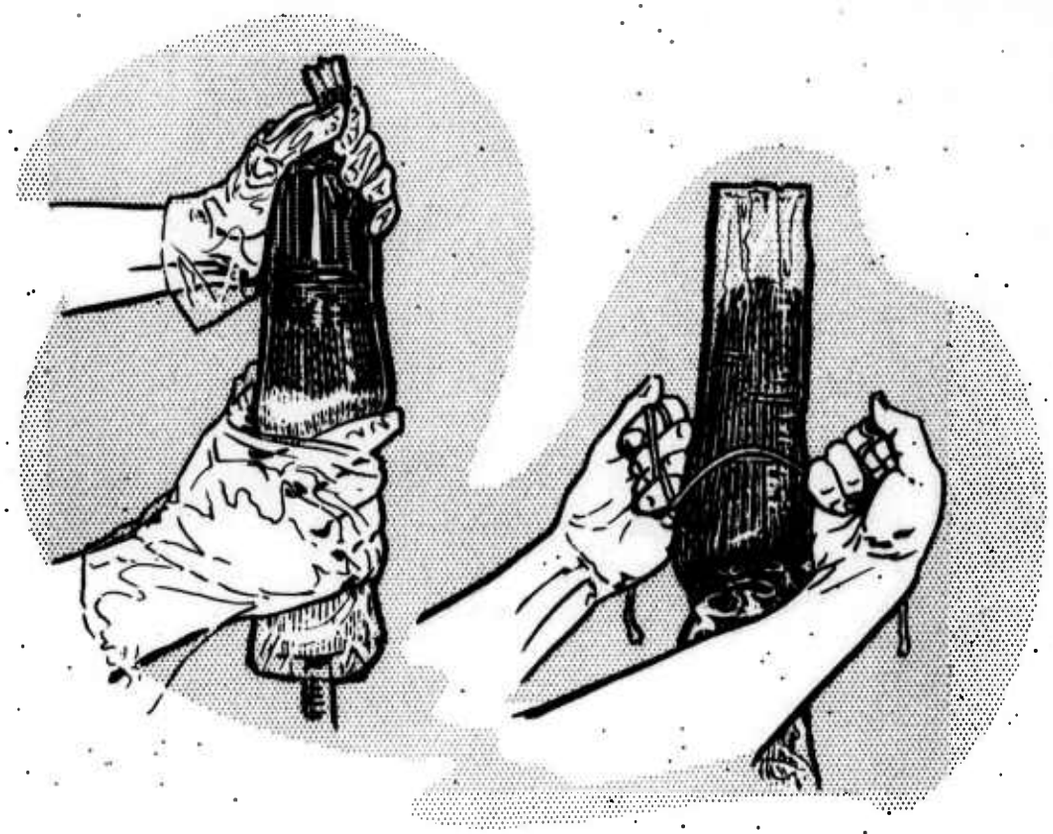
Step 10. Prepare Resin

Use Table I for a guide and prepare a batch of resin mixture sufficient to impregnate both inner socket and outer forearm. *(250 g. of resin mixture should be sufficient for most layups.)* Add 1 - 3 g. of pigment per 100 g. of resin mixture.



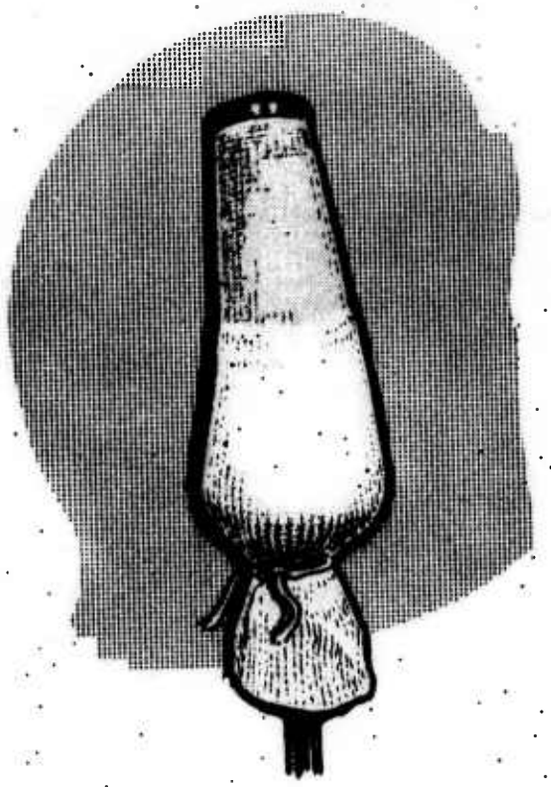
Step 11. Impregnation

Remove the PVA sheet, pull a PVA sleeve down and impregnate the inner socket with the resin mixture.



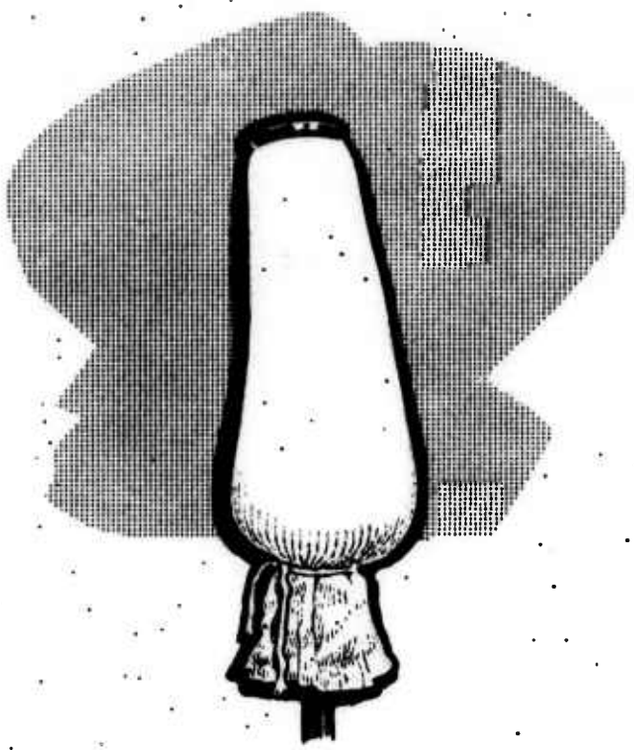
Step 12. Stringing Layup

Use firm, vertical strokes with a string to remove all excess resin from the socket. When a complete stroke of the string shows no resin bead, the PVA sleeve should be removed and any additional resin should be strung out if necessary.



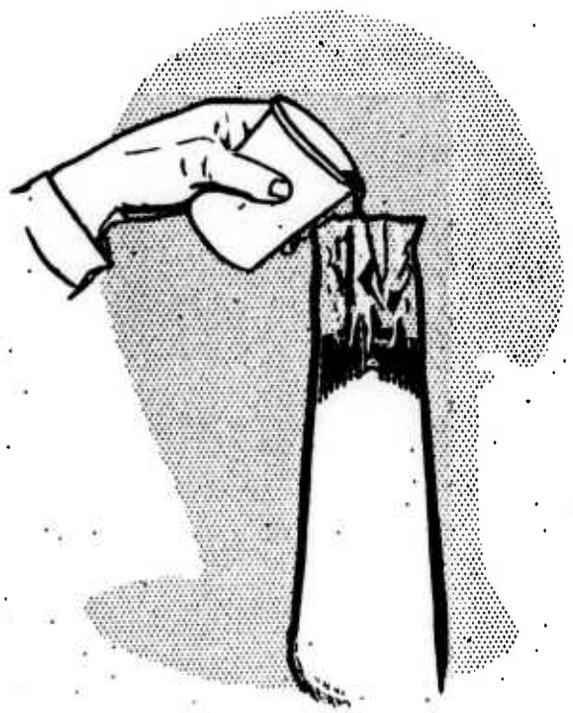
Step 13. Positioning Porous Cone

Pull the porous cone over the socket and align it so that the wrist unit is in the proper position. Tie the stockinet at the base rod.



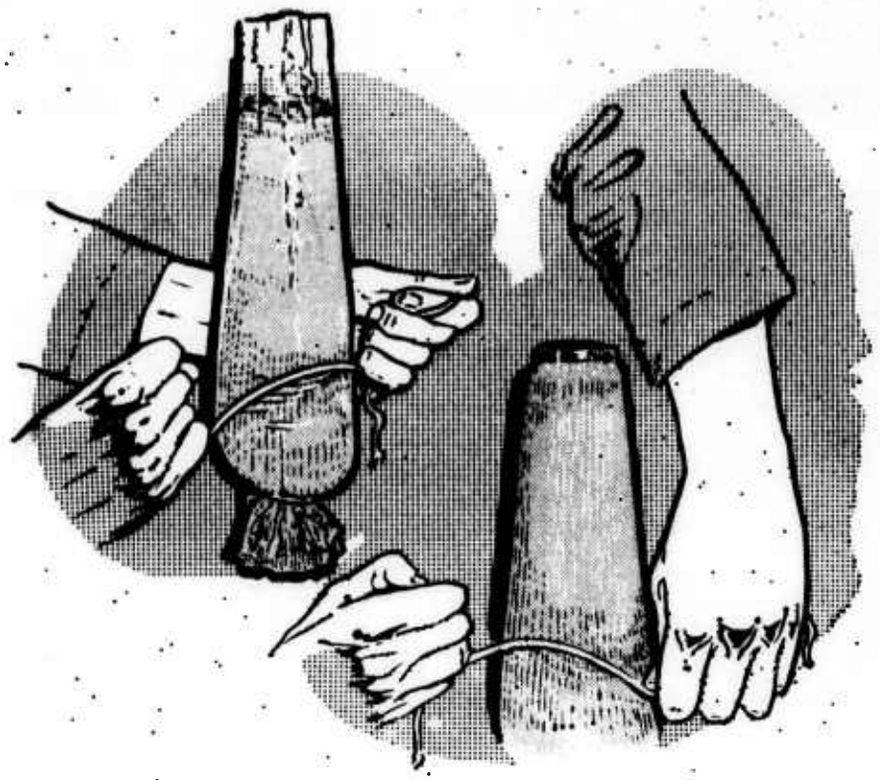
Step 14. Layup Outer Forearm

Cut a piece of Ban Lon stockinet 3 - 5 inches longer than the layup and a piece of orthopedic **stockinet** twice this length. First, tie one end of the Ban Lon stockinet around the wrist unit. **Next,** pull the outer piece of stockinet over this Ban Lon stockinet and tie at the middle around the wrist unit. *(If greater strength is required, use additional layers of stockinet.)* Pull all layers of stockinet down over the layup and tie around the base rod.



Step 15. Impregnate Outer Forearm

Thoroughly impregnate layup with the remaining resin mixture, using a PVA sleeve for the process.



Step 16. String Out Excess Resin

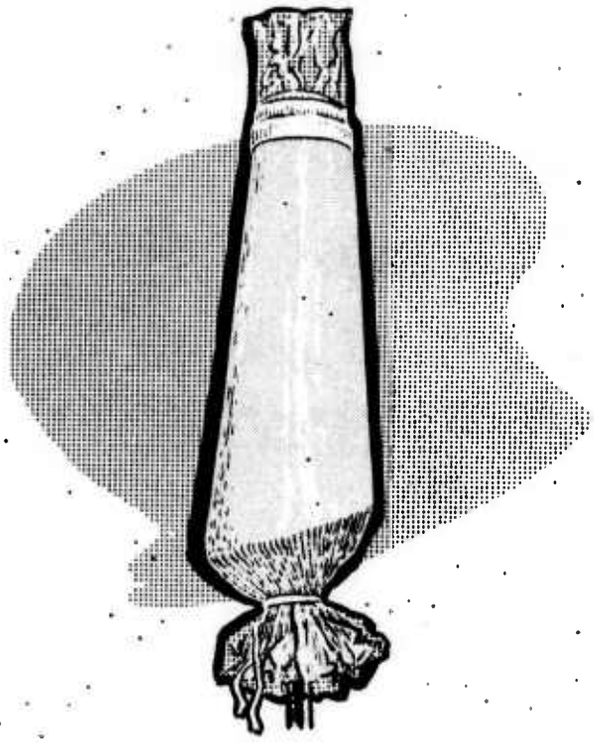
String down all excess resin to the proximal end. It is very important that this step be done thoroughly to prevent pooling of resin when a PVA bag is pulled down in a subsequent step. After stringing down, remove PVA sleeve and again string any excess resin out of the layup. Wrap a few pieces of scrap stockinet around the base pipe to absorb any excess resin.

Step 17. Pre-cure

Place layup in an oven pre-set at 47° C (115° F) for 30 minutes. This will allow the solvent *(trichloroethylene)* to evaporate and leave the layup porous. While the layup is pre-curing, make a PVA sleeve to fit the forearm. Wrap the sleeve in a moistened towel 10 - 15 minutes before the end of the pre-cure cycle. At the end of the 30 minutes, remove laminate and string out any resin that has pooled in the layup. Increase the oven temperature to 100° C (212 ° F) in preparation for a later step.

Step 18. Surface Molding

Take a moistened PVA sleeve, shiny side in, and pull it over the layup so that the entire laminate is in firm contact with the sleeve. If sufficiently moist, the sleeve will slide easily over the layup without causing any resin pools.



If any resin pools are present, string them out of the laminate. Tape the PVA sleeve around the wrist unit and any undercut areas to insure proper lamination. *NOTE: If a non-gloss finish is desired, omit this step and proceed with Step 19. The omission of this step (No. 18) will result not only in a non-gloss outer surface but in a laminate of greater porosity.*

Step 19. Initial Cure

Place the layup into the 100° C (212° F) oven for 60 minutes. This will allow the PVA sleeve to mold the laminate and give it a smooth surface. At the end of the 60 minutes, remove the laminate and strip off the PVA sleeve. The laminate should be tack free.

Step 20. Final Cure

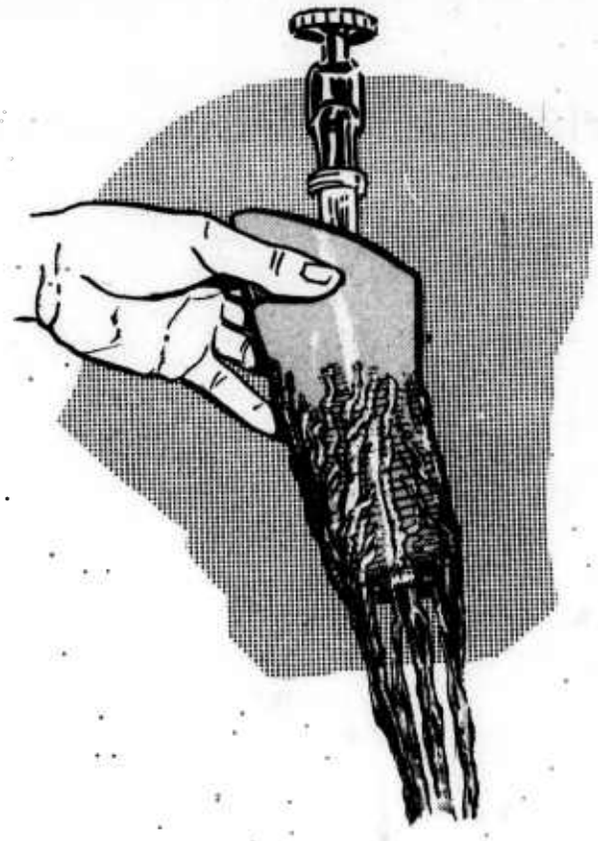
Replace into the 100° C (212° F) oven for 75 minutes for the final cure.

Step 21. Mold Removal

Remove mold from oven and cut to the desired length. The laminate should separate easily from the mold.

Step 22. Trim

Hold the prosthesis firmly on the amputee's stump and mark the trim line. Remove the socket and trim.



Step 23. Test Porosity

Hold the laminate under the tap and allow the water to flow through it. If the laminate has been properly made, the water should pour through the walls of the prosthesis at a high rate.

Step 24. Harnessing

Complete harnessing in the usual manner.

LONG BE STUMPS AND WRIST DISARTICULATIONS

MODIFIED MYLAR CONE METHOD

SECTION V. PART B. MYLAR CONE METHOD MODIFIED FOR LONG-BELOW ELBOW STUMPS AND WRIST DISARTICULATIONS

Step 1. Prepare Stump Model

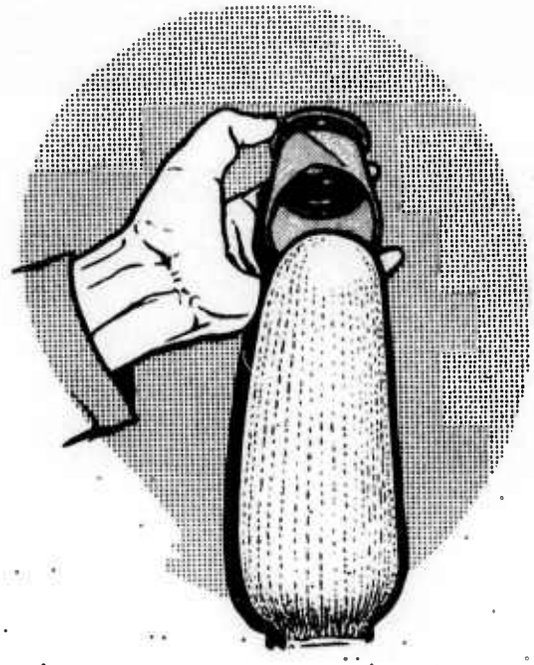
Prepare the stump model in the usual manner, place in vise, distal end up, and coat with Hi-Glo. Allow coating to dry, then pull a moistened sheet or sleeve of PVA down over model and tie at base rod.

Step 2. Layup

Sew the stockinet to fit the contour of the stump. Use one layer Ban Lon stockinet and three to four layers of regular stockinet. Turn Ban Lon stockinet inside out and pull over mold, follow with orthopedic stockinet. Tie all pieces at base pipe.

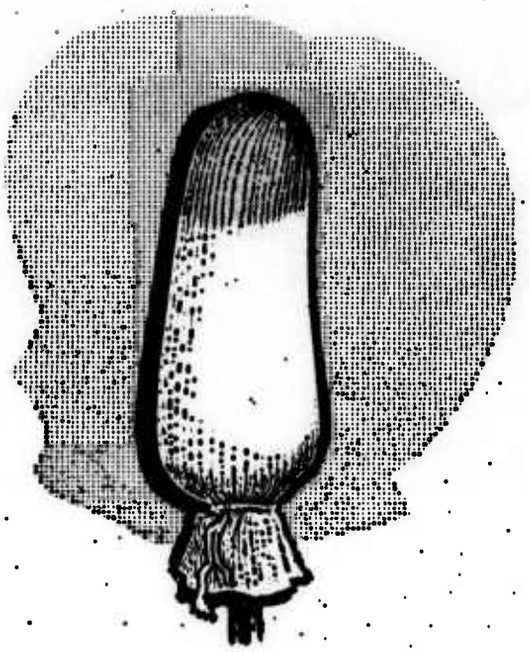
Step 3. Mylar Cone

Cut a sheet of Mylar and wrap it around the wrist unit to form a cone. Fit the cone over the end of the stump. As an area of the outer forearm that is covered with the Mylar will be non-porous, it is desirable to have as short a cone as possible. Adjust the wrist uait so that it is at the proper distance from the epicondyle and tape the unit to the cone, leaving as much as possible of the wrist area free to bond to the laminate, and then tape the seam of the cone closed.



Step 4. Mix Resin

Use Table I as a guide and prepare a batch of resin mixture sufficient to impregnate the layup. *(250 g. of resin mixture should be sufficient for most layups. Add 1 - 3 g. of pigment per 100 g. of resin mixture.)*



Step 5. Impregnate Distal End

Remove the Mylar cone from the layup and brush-coat the area that was underneath. String out excess resin.

Step 6. Outer Layup

Replace Mylar cone and re-adjust to obtain proper alignment of the wrist unit. Take a piece of Ban Lon stockinet several inches longer than the layup and turn it inside out. Pull one end about an inch proximal to the end of the wrist unit and tie at the unit. Trim the excess stockinet that is proximal to the wrist unit. Now cut a piece of orthopedic stockinet 8 - 10 inches longer than twice the length of the layup. Hold the Ban Lon stockinet extended, distal to wrist unit, and pull the orthopedic stockinet over the Ban Lon stockinet and entirely over the layup so that the middle of the orthopedic stockinet is as the wrist unit, and tie at the wrist unit. *(If additional strength is necessary, tie the required pieces on the layup at this step in the procedure.)* Next, pull the two extended pieces back down over the wrist unit and layup, stretch tight, and tie to the base rod.

Step 7. Impregnation

Use the remaining resin to thoroughly impregnate the stockinet by using a PVA bag. When the entire layup has been impregnated, string down the layup as described in Section V, Part A, Step 12.

Step 8. Pre-cure

Place layup into a pre-set oven 47° C (115° F) for 30 minutes to allow the solvent *(trichloroethylene)* to evaporate.

Step 9. PVA Sleeve

While layup is pre-curing, prepare a PVA sleeve in the usual manner. Wrap the sleeve in a damp towel during the final 15 minutes of the pre-cure.

Step 10. Surface Molding

Remove the layup from the pre-cure oven and pull the moistened PVA sleeve down over the layup until the sleeve is in total contact with the laminate. *(NOTE: Sleeve should be sufficiently moist so that it will slide easily over the layup.)* Tape the PVA sleeve around the wrist unit and any severely undercut areas. DO NOT HAVE PVA TOO SNUG AS THIS MAY CAUSE COLLAPSE OF THE MYLAR CONE WHEN THE PVA SLEEVE SHRINKS UPON DRYING.

Step 11. Initial Cure

Place layup into a pre-set oven 100° C (212° F) for 60 minutes.

Step 12. Remove PVA SLEEVE

Take the laminate out of the oven and remove the PVA sleeve. The laminate should be rigid and tack free at this step in the procedure.

Step 13. Final Cure

Replace laminate into oven 100° C (212° F) for an additional 75 minutes to obtain the optimum properties.

Step 14. Mold Removal

Remove laminate from the oven and cut the layup from the mold. The laminate should separate easily from the mold.

Step 15. Trim and Assemble

Hold prosthesis firmly on amputee's stump and mark the trim line. Remove the socket and trim. Complete harnessing in the usual manner.

ACKNOWLEDGEMENT

We wish to express our appreciation to the personnel of the laboratory's Research Limb Shop for their assistance in testing the procedures described in this report.

The technique described in Section V-B was developed by Robert E. Plumb of the Research Limb Shop.

We wish to express our appreciation to Mr. P. Lowe of the Armed Forces Institute of Pathology for drawing the illustrations.

APPENDIX

MATERIALS	MANUFACTURERS
Curing Agent T-1	Shell Chemical Company, 380 Madison Avenue, New York, New York
Epon 815	Shell Chemical Company, 380 Madison Avenue, New York, New York
ERL 2793	Union Carbide Chemical Company, 30 E. 42nd Street, New York, New York
ERL 2795	Union Carbide Chemical Company, 30 E. 42nd Street, New York, New York
Versamid 140	General Mills Chemical Division Kankakee, Illinois
Hi-Glo	Western States Lacquer Company, Dallas 12, Texas
Ban-Lon	The Adler Company, Cincinnati 14, Ohio
Trichloroethyelene	Any Chemical Supply House
Mapico Pigments	Binney & Smith Company, 41 E. 42nd Street, New York, New York
Titanox	Titanium Pigment Corporation, 111 Broadway, New York, New York

ABSTRACT CARD

TITLE: Porous Laminates

AUTHOR(S): James T. Hill
AGENCY: USA Prosthetics Res. Lab.
Walter Reed AMC, Washington 12, D. C.
TECH. RPT. 6204 UNCLASSIFIED
Project 6X59-01-001-04
ABSTRACT: Techniques for the fabrication of porous plastic prostheses for above and below elbow amputees are presented. The presentation is arranged in shop manual form for use by prosthetists.

AD _____ # _____

1. Porous Laminates
2. Porous Prostheses
3. Upper Extremities
4. BE and AE Fabricating Techniques

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15 MAY 1961

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